Department for Transport

Integrated Rail Plan for the North and Midlands

Technical Annex

The analysis presented in this technical annex provides supporting evidence for the decisions made in the Integrated Rail Plan based on work undertaken in 2020 and 2021. The latest economic analysis for High Speed Rail (Crewe-Manchester) Bill is published in the update on the Strategic Outline Business Case accompanying the deposit of the Bill.

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Department for Transport
Great Minster House
33 Horseferry Road
London
SW1P 4DR

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Any enquiries regarding this publication should be sent to us at www.gov.uk/government/organisations/department-for-transport

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1 Executive summary

1.1 This technical annex sets out the analysis and evidence developed by the Department for Transport which has supported the development of the Integrated Rail Plan (IRP) and the options for the schemes it covers.

1.2 The IRP seeks to address major capacity, frequency, reliability, and speed shortfalls on the existing network; maximise integration with existing local transport networks; serve destinations people want to reach; deliver carbon savings; avoid disadvantaging existing passengers and users; and minimise the impact on communities, especially those which don't benefit directly. It sits at the heart of the Government's plans to level up the whole country, build back better, and move to net zero greenhouse gas emissions. It seeks to deliver the frequent and reliable services that millions of rail users in the North and Midlands deserve. We intend to take an adaptive approach to investment, allowing the programmes set out in this Plan to evolve in the light of future demand and cost information. That means we are – as the National Infrastructure Commission (NIC) recommended – setting out a core pipeline of commitments now, recognising that other potential future schemes could be added, if these projects are delivered on time, to budget, and depending on how demand and economic growth recover.

1.3 In developing the evidence base to support decisions on the IRP the aim has been to assess the different options for the schemes within the plan against its strategic objectives, including an early assessment of value for money (VfM). This is a proportionate approach to the assessment of the various schemes at this early stage in their development to support decisions around preferred options for the IRP. More detailed analysis will be completed as individual schemes are taken forward and business cases developed in line with HMT Green Book and Transport Analysis Guidance (TAG).

1.4 The IRP is being published against a background of increased uncertainty about the future of demand for rail travel as the country recovers from the COVID-19 pandemic. Options appraisal requires us to forecast demand over the long-term over which uncertainty is likely to increase. The analysis has taken post-COVID economic and population forecasts from the Office of Budget Responsibility (OBR) and Office of National Statistics (ONS) and has accounted for wider uncertainty by following the principles set out in the TAG uncertainty toolkit, testing scenarios around future travel demand to understand how options perform under different scenarios.

1.5 The schemes set out in the IRP will have long-term impacts. The economic lifetime of these assets is very likely to extend beyond the standard appraisal period of 60 years, particularly where new lines are being proposed. Recent updates to TAG allow the use of a longer appraisal period where it can be demonstrated that the proposed scheme will have impacts over that period. The Value for Money assessment presented here reflects sensitivity testing around a longer (100-year) appraisal period as well as the standard 60-year appraisal.

1.6 Investment in rail in the North and Midlands will play a key role in supporting Government objectives to level up the economy. In making these decisions we have acknowledged the NIC's findings that significant productivity improvements could flow if the major cities of the North and Midlands functioned more like a single economy and individual city regions were supported to fulfil their economic potential. However, given the early stage of scheme development, full analysis of the wider economic impacts of the different options has not been completed, in particular to understand the dynamic impact of new infrastructure on land-use, employment and population growth in the areas served. The value for money assessment reflects a limited assessment of impacts on productivity based on reductions in journey times which bring businesses closer together. More detailed analysis will be completed as individual business cases are taken forward.

1.7 The IRP will also play a part in supporting the Government's decarbonisation objectives. A qualitative assessment of the likely carbon impacts of the various options is presented, which has considered both the carbon emissions associated with construction and the operational impacts of running services. Benefits associated with a shift from more carbon-intensive transport modes have not been explicitly included in the assessment and will be further analysed as schemes are developed. The NIC Rail Needs Assessment also presented an assessment of lifecycle carbon emissions.

1.8 A key consideration is value for the taxpayer. Alongside the consideration of performance against strategic objectives, VfM ranges for each of the options for the individual schemes are presented. The VfM assessment includes estimates of the wider economic impacts of the options (assuming no land-use change) but (as noted above) does not incorporate any quantified estimate of the dynamic economic impacts, that is the impacts brought about by households and firms relocating in response to the investment. The VfM assessment has been used to make a relative assessment between the options in each scheme in addition to the wider multi-criteria analysis.

1.9 The results of the analysis are presented in multi-criteria analysis tables which summarise both the quantitative and qualitative elements of the assessment. These set out how different options deliver against the objectives of the IRP and demonstrate the trade-offs to be made when considering the different options within each scheme.

1.10 For Eastern Leg options, the analysis shows that the full Eastern Leg as originally planned and two other alternatives to it - the Greengauge 21 proposal via Nottingham, Newark and the East Coast Main Line, and an alternative involving the upgrade of the Erewash Valley line, with high-speed line part of the way between Sheffield and Leeds - cost significantly more than the core option chosen

in the IRP and have lower VfM. The full Eastern Leg delivers a faster journey time from London to Leeds, the same journey time to Sheffield and slower journey time to Derby and Nottingham than the core option we have chosen. It would also mean that some places on the existing main lines receive poorer services than now; others see no improvement; the northern section of the Midland Main Line remains diesel-operated for the foreseeable future; and the East Coast Main Line receives no upgrades beyond those already in progress. These factors and its cost reduce the extent to which the full Eastern Leg delivers value for money, and, over a 60-year appraisal period, it has been assessed as Poor to Low value for money. The full newbuild scheme also delivers a capacity increase of over 400%, in excess of actual future demand under any realistic scenario. The longer delivery timeframe for the full Eastern Leg option also means that it is slower to deliver the assessed benefits.

1.11 For Northern Powerhouse Rail, Government committed to the Manchester-Leeds element of the scheme. Three options were put forward for this section by Transport for the North in the 2019 NPR Strategic Outline Business Case (SOBC) as part of proposals for a wider network: full high-speed newbuild between Leeds and Manchester via central Bradford (preferred by TfN), full high-speed newbuild via a parkway station at Bradford, or a hybrid option via Huddersfield using a mixture of upgraded conventional line and newbuild high-speed line. We have chosen the latter option, and additionally included new high-speed and upgraded line between Manchester and Liverpool, between Leeds and York and upgrades to the existing line between Bradford and Leeds.

1.12 The analysis suggests that the core option chosen by the IRP delivers similar journey times (and the same level of NPR services) in the Manchester-Liverpool and Manchester-Leeds corridors as TfN's preferred options, is likely to represent higher VfM and costs at least £18bn less than the cost of TfN's preferred option for the same corridors

1.13 Since the original analysis of the HS2 and NPR options was done, there have been updates to the models used and further development of the standard analytical tools. The analysis emerging from this process suggests that the model updates will lead to benefits and revenues for all Eastern Leg options being reduced by around 25% and 40% respectively, while for NPR options benefits will increase by 25% and revenues by 20%. The model updates are not anticipated to materially change the conclusions of the report.

2 Overview of Analytical Approach

2.1 This technical annex presents the analysis and evidence that has supported the development of the Integrated Rail Plan (IRP). It provides an overview of the analytical approach taken in assessing the options presented in the IRP, the assumptions underpinning the analysis, the tools and methods used and summarises the outputs from the analysis.

2.2 The IRP sets out a plan for rail investment in the North and the Midlands including how the Government intends to take forward: High Speed 2 including decisions on HS2 Crewe - Manchester and Eastern Leg, Northern Powerhouse Rail (NPR), and Midlands Engine Rail. The analysis has been developed with the aim of understanding how different options under consideration for these schemes will deliver against the strategic objectives of the IRP alongside a value for money assessment. The key objectives for the IRP are:

a. **Improving transport for users by enhancing capacity and connectivity**

b. **Growing and levelling up the economy**

c. **Reducing environmental impact by supporting decarbonisation of the rail network and accelerating modal shift**

d. **Ensuring value for the taxpayer through efficient delivery of rail infrastructure**

2.3 To deliver this strategic assessment a mix of quantitative and qualitative analysis has been carried out to develop a multi-criteria analysis for options within each scheme. This is a proportionate approach to the assessment of the various schemes at this stage in their development and has supported decisions around preferred options for the IRP. As individual schemes are taken forward following the publication of the IRP, more detailed analysis will be completed and estimates of costs and benefits refined as business cases are developed in line with HMT Green Book and Transport Analysis Guidance (TAG).

Value for Money assessment

2.4 Value for money (VfM) is a key output of economic appraisal which takes account of both monetised and non-monetised impacts. The initial VfM assessment is underpinned by a benefit-cost ratio (BCR) generated by quantifying and monetising benefits with the aim of estimating the benefit to society associated with a given level of expenditure. DfT's Value for Money Framework sets out how BCRs provide the starting point for assessing the VfM category (Figure 1). However, it should be noted that the final VfM category should also take account of indicative monetised and non-monetised impacts which are not directly captured in the BCR.

Figure 1: VfM categories

VfM Category	Implied Benefit Cost Ratio
Poor	Less than 1.0
Low	Between 1.0 and 1.5
Medium	Between 1.5 and 2.0
High	Between 2.0 and 4.0
Very High	Greater than 4.0

2.5 The VfM analysis presented here is underpinned by modelled outputs for transport user benefits and revenue impacts for the different options (also known as Level 1 impacts). In addition, an assessment of impacts on the wider economy (assuming no change in land use) has been made, specifically 'static' agglomeration effects which estimate productivity improvements that result from increasing the effective density of places and therefore the opportunity for positive spill over effects (Level 2 impacts). Further assessment of wider economic impacts will be carried out at a later stage of scheme development.

2.6 The IRP is being published against a background of increased uncertainty about the future of demand for rail travel as the country recovers from the COVID-19 pandemic. Options appraisal requires us to forecast rail demand over a 60 or 100-year appraisal period in the face of significant uncertainty. Demand forecasts are underpinned by post-COVID economic and population forecasts from July 2020 and we have further accounted for uncertainty around behaviour change, following the principles set out in the TAG uncertainty toolkit, by testing sensitivities around future travel demand to understand how different options perform. Further detail of the sensitivity analysis undertaken is presented in section 4.

2.7 The VfM assessment includes the expected costs to the Government for the scheme options within the IRP. This includes the capital costs of constructing the railway and the operating costs of running it. The revenue from additional rail passengers or longer journeys is deducted from those costs to calculate the net impact to the public sector purse.

2.8 The capital cost assumptions for all scheme options under the IRP are based on the latest cost information produced by scheme promoters and held by the Department. Costs for Eastern Leg options have been taken from work conducted by HS2 Ltd,

Network Rail and Mott MacDonald, and costs for NPR have been taken from work conducted by Network Rail and HS2 Ltd. In line with TAG, optimism bias is applied to these cost estimates to reflect the inherent risks and uncertainties associated with them. As the IRP has drawn together many different costs on different scheme options, from different sources and with varying levels of maturity, optimism bias estimates have been adjusted accordingly.

2.9 Both costs and benefits are estimated over a standard 60-year appraisal period in line with TAG. Recent changes to TAG allow impacts to be estimated over a longer appraisal period (up to 100 years) where a project's design life is longer than this. Given the nature of the schemes in the IRP which reflect significant investment in new lines and infrastructure, it is reasonable to assess their impacts over this longer time frame. As a result, both 60-year and 100-year VfM ranges are presented, capturing uncertainty around future demand as well as the impact of a longer appraisal period.

Assessment against strategic objectives

2.10 The updated HM Treasury Green Book (Box 18) clarifies that VfM is a judgement based on consideration of different factors to be presented to decision makers. It is considered as part of the five-case business case alongside other analysis and evidence which demonstrates the extent to which options meet strategic objectives. This annex sets out the analysis, both quantitative and qualitative, which has been carried out in support of this assessment.

Figure 2: Criteria framework for strategic assessment of options

Strategic Objective	Criteria	Assessment
Enhance capacity and connectivity	Rail network connectivity boost	Journey time outputs developed by scheme development teams. Faster journey times are ranked higher.
	Rail network capacity boost	Seating capacity outputs generated by scheme development teams. Greater seating capacity ranked higher.
Grow and Level up the Economy	Levelling up impact	Description of potential impact of transport investment on the wider economy.
Reduce environmental impact by supporting decarbonisation and accelerate modal shift	Potential contribution to carbon targets and objectives	Qualitative assessment of carbon impacts based on length of new high-speed line construction, and efficiency of operation.
	Impact on local natural and townscape environments	Qualitative assessment of the extent to which local impacts on natural and townscape environments can be mitigated. Assumption that construction of new lines is more disruptive to natural environments than upgrades and more difficult to mitigate.
Ensuring value for the taxpayer through efficient delivery of rail infrastructure	Delivery timescales	Delivery into service dates estimated by scheme development teams.
	Disruption to existing rail network during delivery	Qualitative assessment based on extent to which option requires upgrades to existing network.
	Affordability	Estimated costs from HS2 Ltd/Network Rail for different options. Lowest cost option is ranked highest in terms of affordability.
	Value for Money	Value for money assessment based on benefit-cost ratios developed using model outputs.

Grow and Level Up the Economy

2.11 The IRP sets out a package of investment in the rail network in the Midlands and North in support of Government's levelling up objectives. The National Infrastructure Commission recognised the opportunity for significant productivity improvements if the major cities of the North and Midlands functioned as a single economy. Transport can bring about productivity impacts when improvements to journey times bring businesses closer together, improving collaboration, competition, and innovation.

2.12 Given the early stage of development of the options under consideration in the IRP, it has not been possible to fully assess their impacts on the wider economy, particularly those associated with households and businesses changing location in response to the investment (dynamic impacts). While the spatial distribution of transport user benefits can provide some insight into the potential for investment to support levelling up objectives in particular places, taken alone it does not provide information about the local context which is relevant when considering how transport investment will impact on the economy, as set out in TAG guidance.

2.13 More detailed analysis of the wider impacts of the schemes in the IRP package will be taken forward as individual business cases are developed. This will require the development of an economic narrative which will set out how schemes will deliver impacts on the wider economy within a local context and consider complementary action to deliver on the government's levelling up objectives alongside transport interventions.

Enhance capacity and connectivity

2.14 We have assessed the extent to which different options deliver journey time savings and seat capacity improvements, considering the magnitude of the positive impacts delivered and how widespread those impacts are across the network and key corridors. Improvements to journey times and capacity are based on assumed rolling stock types and technical information on timetabling and achievable journey times.

Reduce environmental impact by supporting decarbonisation and accelerate modal shift

2.15 We have made a qualitative assessment of the degree to which different options are compatible with Government's net zero carbon target. New rail infrastructure and upgrades can impact on carbon emissions in three ways:

a) Capital carbon: carbon embedded in construction materials and processes.
b) Changes in operational emissions driven by running new services or switching between diesel and electric services.
c) Changes in emissions in other transport modes due to modal switching.

2.16 In making a qualitative assessment the assumption is that capital carbon will be higher for options where new infrastructure is built, as opposed to upgrades to existing lines where the quantity of new materials required will be less, and will

require greater carbon savings from modal shift or operational savings to offset. However, we anticipate that all options offer the potential to switch away from more carbon intensive transport modes, and where there is a move from diesel to electric services, the impacts are likely to be neutral or somewhat positive. The assessment does not include explicit consideration of the magnitude of the mode shift impacts of different options though it should be noted that greater operational savings or modal shift may be required to offset greater construction impacts. The NIC Rail Needs Assessment presents a quantified assessment of lifecycle carbon emissions across the three packages considered.

2.17 A qualitative assessment has also been made of the extent to which adverse impacts on local natural and townscape environments can be mitigated. While we assume all impacts can be mitigated, the assessment captures the mitigation effort required which varies with the scale of the impact. Options with a more significant negative impact score lower in this assessment.

Ensuring Value for Taxpayer through Efficient Delivery

2.18 Alongside value for money, the criteria used to assess options against the objective of efficient delivery are affordability, delivery timescales and disruption to existing rail network. The assessment of delivery timescales is based on anticipated delivery into service dates. The earlier the potential delivery, the higher the ranking for the option.

2.19 Disruption to the existing rail network is greater where upgrades are made to existing lines. Impacts have been assessed on a scale from “unacceptable/highly significant negative impacts” to “minimal adverse impacts”.

2.20 Affordability considers costs of different options in isolation. The cheaper an option is the more affordable it is deemed to be.

2.21 Greater detail of the options assessed is set out in Section 3. In section 4, a more detailed description is given of the key assumptions and methodology underpinning the VfM assessment and in section 5 the outputs of the multi criteria analysis (including VfM) are presented in summary tables.

3 Summary of IRP options analysed

3.1 Existing options for schemes including High Speed 2 (HS2), Northern Powerhouse Rail (NPR) and others in the North and Midlands have been identified and developed by the Department for Transport (DfT) with partners including HS2 Ltd, Transport for the North (TfN) and Midlands Connect. These scheme options were then further developed and refined in dialogue with third parties.

3.2 Analysis conducted for the IRP has considered a range of alternative options for HS2 Phase 2b Western Leg (Crewe-Manchester) and Eastern Leg, and Northern Powerhouse Rail. Midland Engine Rail options including Midland Mainline electrification and the Midlands Rail Hub have been incorporated within the analysis for the Eastern Leg options.

3.3 Analysis for the IRP has been developed alongside the business case for Phase 2b Western Leg which will be published around the time of deposit of the High Speed Rail (Crewe-Manchester) bill. The business case will provide more detailed analysis and therefore this annex does not present a summary of options or VfM assessment for the Western Leg.

3.4 The schemes being considered in the IRP are at different stages of development and the options that have been assessed do not reflect final decisions on how each scheme might be delivered with the full extent of choices available. However, appraisal of indicative scheme options has allowed the IRP to make recommendations on how schemes can be phased to maximise and deliver benefits sooner, and where further work needs to be completed before decisions are reached, as detailed in the report.

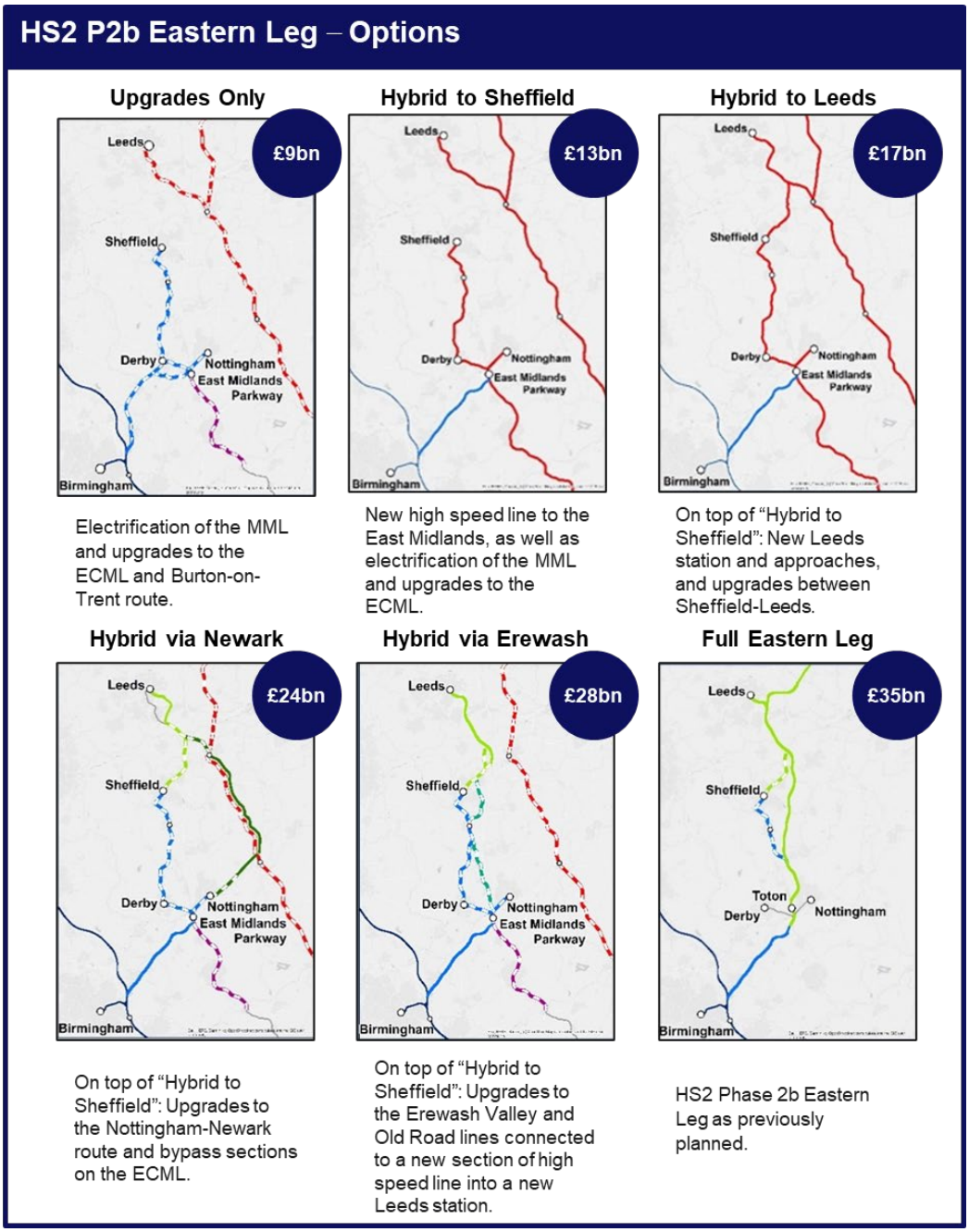
3.5 The options that have been analysed for each scheme are presented in Figures 3 and 4 below. The costs presented are central estimates of financial costs in 2019 prices, including contingency costs. For the purposes of economic appraisal, optimism bias is applied, and costs are discounted.

HS2 Phase 2b Eastern Leg

3.6 The six options considered for the Eastern Leg are a mixture of conventional network upgrades, hybrid options combining conventional network upgrades and new high-speed infrastructure, and the Eastern Leg as previously planned, and have been informed by Mott MacDonald work on strategic alternatives.

3.7 We are looking at the most effective way to run HS2 trains to Leeds, including the most optimal solution for Leeds Station capacity and taking forward work on a Mass Transit System for Leeds and West Yorkshire. The options presented here on taking HS2 to Leeds is not a complete list of the options that will be considered in the study to take HS2 to Leeds.

Figure 3: **Eastern Leg options and costs**



3.8 Six options have been assessed for the Eastern Leg:

- **Upgrades Only:** building a connection between HS2 Phase One and the Burton and Tamworth line. The Midland Main Line is also upgraded and electrified which enables HS2 services to Derby, Nottingham, and Sheffield. Leeds and the North East would continue to be served by East Coast services via an upgraded East Coast Main Line.

- **Hybrid to Sheffield:** building a new high-speed line from the West to East Midlands and electrifying the Midland Main Line from Market Harborough to Nottingham and Sheffield, allowing HS2 services to reach Derby, Nottingham and Sheffield. Leeds and the North East would continue to be served by East Coast services via an upgraded East Coast Main Line.

- **Hybrid to Leeds:** in addition to the above, a new station at Leeds is constructed and connected to the East Coast Main Line. The existing railway is upgraded between Sheffield and Leeds. This option would allow HS2 services to Leeds via a combination of high-speed line and upgraded existing lines.

- **Hybrid via Newark:** in addition to the Hybrid to Sheffield option, a high-speed bypass is constructed east of Nottingham station to the East Coast Main Line north of Newark. A high-speed bypass is also constructed between Newark and Doncaster. This would enable high speed services to Leeds via Nottingham, faster than Hybrid to Leeds, and to reach Newcastle. East Coast services would connect onto the new infrastructure between Newark and Doncaster, cutting journey times from Kings Cross to destinations north of Newark.

- **Hybrid via Erewash:** in addition to the Hybrid to Sheffield option, the Erewash valley and Old Road line is upgraded and electrified. This is then connected to HS2 new line from the Rotherham area to a planned high-speed station at Leeds. The currently planned high speed connection to the ECML near Church Fenton is not constructed, and so York to Newcastle continues to be served by an upgraded ECML.

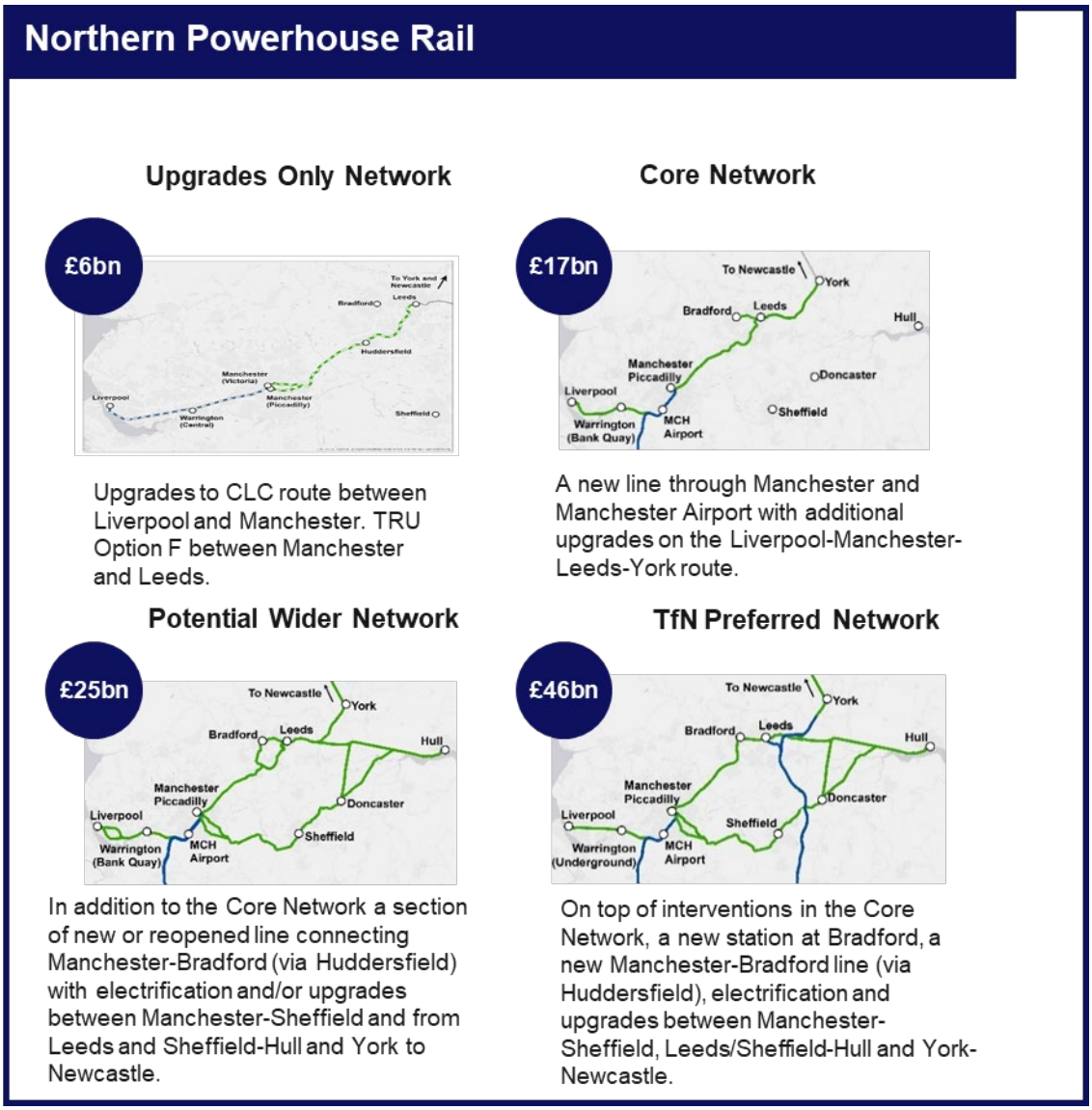
- **Full Eastern Leg:** Completing the Full Eastern Leg broadly as planned. High Speed services would route through Toton and continue on a high-speed line to a new station at Leeds, with a spur to the East Coast Main Line to serve the North East.

3.9 The above options are an indicative set of alternatives to previous HS2 Phase 2b Eastern Leg plans for appraisal purposes, but do not represent an exhaustive list of options. As set out in the IRP, we will conduct a separate study on the most effective way for HS2 services to reach Leeds. More detail on Government proposals for the HS2 Phase 2b Eastern Leg is set out in the main report.

3.10 A VfM assessment has been made for all Eastern Leg options except the Hybrid option via Erewash (although this has been done previously under different assumptions). However, this has been assessed against the IRP's strategic objectives and is shown in the analytical outputs set out in section 5.

Northern Powerhouse Rail

Figure 4: NPR network options and costs



3.10 The Northern Powerhouse Rail (NPR) vision was established in 2015[1], to radically improve connectivity between the major cities of Liverpool, Manchester, Leeds, Sheffield, Hull, and Newcastle, and with Manchester Airport. In 2019, shortly after he came to office, the Prime Minister promised to fund the Manchester-Leeds section of NPR. For this section, and for Manchester to Liverpool, Transport for the North presented us with three different options.

- Option 1 was a mixture of new-build high-speed line, covering roughly half the route from Liverpool to Leeds, and upgrades to the existing lines into Leeds (via Huddersfield) and Liverpool (via Warrington Bank Quay) for the rest of the route.

[1] The Northern Powerhouse: One Agenda, One Economy, One North, The Northern Powerhouse: One Agenda, One Economy, One North (publishing.service.gov.uk)

- Option 2 was for an entirely new-build high-speed line between Leeds and Manchester, including a new station on the outskirts of Bradford; a new line from Warrington to Liverpool (with a parkway station at Warrington); and an underground Piccadilly station with a connection allowing it to be used for Sheffield services.

- Option 3 was the same as Option 2, but with a new central station underground at Warrington (still offering less convenient interchange to Bank Quay), and an underground station in the vicinity of the existing Bradford Interchange station

3.11 All options also included significant upgrades (and, where appropriate, electrification) of the existing railways to Sheffield, Newcastle, and Hull, with the scope of these works somewhat greater in Options 2 and 3. TfN's preference was for Option 3. Since 2019, extensive work has been done to refine these options and consider the costs and benefits of different choices. The NIC's key findings were that prioritising regional links, such as those from Birmingham to Nottingham and Manchester to Leeds, has the potential to deliver the highest benefits, and that prioritising regional links performs better compared to long-distance links.

3.12 The IRP is focused on delivering the core of an NPR network now, as Liverpool City Region, West Yorkshire and Greater Manchester represent the three largest economic areas in the North and better connecting them will deliver the majority of the benefits of the NPR schemes. For the purposes of appraisal, the IRP has assessed four potential networks ranging from upgrades to existing lines along the core route, to new lines connecting the core route and upgrades to surrounding towns and cities:

- **Upgrades Only:** upgrades to the Cheshire Lines Committee (CLC) route between Liverpool and Manchester along with the Transpennine Route Upgrade (TRU) between Manchester and York.

- **Core Network:** Upgrades to the core NPR Liverpool-York including Manchester Airport and Transpennine routes, with substantial new high-speed line between Standedge and Warrington via Manchester Piccadilly and Airport stations. Also includes improvements to the existing line between Bradford and Leeds.

- **Wider Network:** This includes the options in the Core Network along with a section of new or reopened line connecting Manchester-Bradford (via Huddersfield) with electrification and/or upgrades between Manchester-Sheffield, and from Leeds and Sheffield-Hull and York to Newcastle. This is very similar to Option 1 from the 2019 SOBC as described in paragraph 3.10.

- **TfN Preferred Network:** mostly new high-speed line between Liverpool-Manchester, Bradford, and Leeds, with new stations at Liverpool, Warrington (underground) and Bradford, and line upgrades to surrounding areas.

3.13 Full economic VfM modelling has to date only been conducted on the NPR Wider and TfN Preferred Networks, as alternative options were developed as the IRP has been taken forward. All NPR options have been assessed against the IRP's strategic objectives and are reflected in the multi-criteria analysis table presented in section 5.

Total IRP Package

3.14 Based on the analysis outlined in this document, the IRP has considered a total package of rail interventions totalling £96.4bn (with a range from £84.7 – 104.2bn). As well as commitments to HS2 Phase 2b Western Leg (Crewe-Manchester), the Eastern Leg Hybrid to Sheffield and the Core NPR Network, this includes remaining costs on HS2 Phase 1 and 2a, and smaller rail schemes in the North and Midlands.

Figure 5: IRP core package - scheme costs

Scheme	Cost (2019 prices)
Remaining costs for HS2 Phases 1 and 2a (March 2020 onwards)	42.5
HS2 Phase 2b Western Leg (including Golborne link)	17.0
Smaller rail schemes (North / Midlands) until 2025	1.5
Transpennine Route Upgrade (TRU) option F (base scope including full electrification)	5.4
HS2 East Core Network (including HS2 Eastern Leg, Midland Main Line and East Coast upgrade)	12.8
NPR Core Liverpool-York (including TRU Option G enhancement)	17.2
TOTAL	**96.4**

4 Value for Money

Detailed assumptions

4.1 The Value for Money (VfM) assessment for any piece of transport infrastructure aims to provide a comprehensive overview of an option's impacts and, as far as possible, place an evidence-based value on them. To ensure this is comprehensive in its scope, our economic case framework considers economic, environmental, and social impacts.

4.2 The assessment conducted for the IRP incorporates a range of evidence generated by a variety of analytical tools, with analytical assumptions aligned and in accordance with the Department's Transport Analysis Guidance (TAG) and the HMT Green Book. This ensures comparability and robustness across the evidence base. The analysis incorporates post-COVID economic and population growth forecasts from the Office of Budget Responsibility (OBR) and Office of National Statistics (ONS) from July 2020.

4.3 However, recognising the early stage of development of many of the options presented here, it was judged disproportionate to quantify and monetise all potential impacts at this stage. Impacts which have not been incorporated in VfM analysis at this stage include: consideration of reliability and train performance, environmental impacts, and residual value of investments, as well as the dynamic economy impacts which capture the location decisions of households and businesses in response to the investment.

4.4 Instead, alongside detailed transport modelling of schemes and options, we have completed a strategic assessment (based on both quantitative and qualitative evidence) of other relevant impacts. The strategic assessment includes consideration of carbon impacts, the extent to which local adverse impacts on natural environment can be mitigated and transport disruption, as well as delivery timescales and affordability. This followed from the work that the NIC has done which also considered impacts on productivity and economic growth as well as lifecycle carbon emissions.

4.5 This section sets out the detailed assumptions underpinning the VfM assessment, including:

a) Costs of different options taken from HS2 Ltd/ Network Rail/Mott Macdonald estimates – with varying maturities of designs and levels of contingency adjusted in accordance with TAG (more detail is provided in Costs section);

b) The models used to estimate benefits and revenues for HS2 and NPR options;

c) The sensitivities tested in the analysis to reflect key uncertainties.

4.6 Since the analysis presented in this annex was completed, there have been updates to both modelling and appraisal frameworks. A brief description of the emerging results is provided below.

4.7 The analysis carried out is proportionate relative to the early stage of developments of the options and the strategic nature of the IRP. This approach allows considered judgements of the relative VfM of options for a given scheme (e.g. HS2 options compared amongst themselves, NPR options compared amongst themselves), alongside a number of other strategic objectives.

Benefits

4.8 The first stage in developing the VfM assessment is to estimate the benefits in terms of impacts on transport users (e.g. journey time savings, reductions in crowding) and on the wider economy in terms of productivity impacts, relative to the costs of constructing and operating the schemes.

4.9 The estimated benefits and revenues of IRP schemes are drawn from two sources:

- The PLANET Framework Model (PFM) version 9 for HS2 related options
- The Northern Rail Modelling System (NoRMS) version 1D for Northern Powerhouse Rail options.

4.10 PFM and NoRMS are complex peer-reviewed models that provide views of the rail, road, and air markets, drawing on detailed information on passenger travel from ticket sales and other data. PFM is more strategic in nature, with a focus on long-distance inter-city flows, while NoRMS offers a more detailed view of the north and was developed for use in the Northern Powerhouse Rail business case. As part of its development process, NoRMS has been sense-checked against the industry standard MOIRA2 rail model.

4.11 Since the analysis for the IRP was undertaken, both PFM and NoRMS have undergone further development with new versions (PFMv10.1 and NoRMS 2) becoming available. Emerging analysis suggests that the model updates will lead to benefits and revenues for Eastern Leg options being reduced by around 25% and 40% respectively, while for NPR options benefits will increase by 25% and revenues by 20%.

4.12 Minor changes have been made to the networks since the analysis was undertaken, as a result the networks modelled are not an exact replica of those presented in the IRP but this is not expected to materially impact the VfM assessment.

4.13 Emerging results suggest that the VfM assessment for the Eastern Leg informed by the updated models is likely to remain within the ranges presented here. The VfM range for NPR is expected to rise but is yet to be confirmed. The model updates are not anticipated to materially change the conclusions of the report.

4.14 While a full analysis of the Wider Economic Impacts of the scheme options has not been completed at this stage, estimates have been made of 'static' economic effects: these capture changes brought about by effectively bringing businesses closer together through reducing journey times: productivity impacts, labour supply impacts and the benefits of greater competition between businesses. Estimates have been made for HS2 Phase 2b Western Leg and the full network using version 2.0 of the Wider Impacts in Transport Appraisal (WITA) tool. This full network uplift has been applied to Eastern Leg options to provide an estimate of productivity impacts for the different options considered. Where impacts have not been directly estimated in WITA, off-model adjustments have been made to capture wider economic impacts for relevant options. Wider Economic Impacts for NPR have been estimated using an adaption of WITA developed by TfN specifically for the scheme.

4.15 Dynamic impacts resulting from second order transformational effects, such as land use change driven by households and firms choosing to relocate in response to transport investment have not been captured in this assessment. Assessing the scale of these impacts requires the use of complex modelling which was not feasible in the analytical timescales for the IRP or the level of scheme maturity. Further consideration will be given to the assessment of these impacts in future business cases.

4.16 As with previous HS2 and NPR economic cases, there is no quantification of potential freight benefits that could arise from the spare capacity generated by HS2 or NPR. Freight services are not modelled in PFM or NoRMS.

Costs

4.17 Estimates of HS2 costs for the Eastern Leg of Phase 2b have been taken from Phase 2b Baseline 2.0, which was adopted in December 2020. A further baseline for the Western Leg only (BL2.1) has been prepared to inform the latest economic analysis for the High Speed Rail (Crewe-Manchester) Bill. For newer, "hybrid" options developed during the IRP, a mixture of HS2 costs for high-speed infrastructure, Network Rail costs (where available) and estimates produced by Mott MacDonald for conventional network upgrades have been used.

4.18 Economic costs for appraisal purposes have been developed using financial cost estimates from the sources above. For some options and alignments costs may have been allocated differently for appraisal purposes than those presented here.

4.19 For NPR, the latest costs from Network Rail and Transport for the North's development work have been used, including an assessment of potential efficiency. For specific HS2 "touchpoints" necessary for NPR, costs have been estimated by HS2 Ltd from Baseline 2.0 third party scope estimates.

4.20 Costs for the Midlands Rail Hub scheme (part of Midlands Engine Rail) have been taken from the 2019 Midlands Rail Hub SOBC.

- While cost ranges have generally been used, typically reflecting different levels of contingency, for the purposes of assessing portfolio affordability the following assumptions have been used (note that analysis was completed before updates to TAG unit A1.2 were made in July 2021 where optimism bias assumptions were updated):

    - For HS2 Phases 1 and 2a, a midpoint between the point-estimate and RCF70 forecast cost has been taken.

    - For HS2 Western Leg and future high-speed line: 44% contingency based on the current RCF70 forecast from HS2 Ltd. For scope being provided for NPR (which has been at an earlier level of design) 44 - 48% contingency is used.

    - For schemes on the conventional network (including NPR), 66% contingency and reduced scope cost estimates in line with DfT TAG.

Figure 6: Summary of data used to create capital cost estimates

	HS2 Phase 2b Eastern Leg	NPR
Sources	HS2 Baseline 2.0 estimates excluding third party scope - *December 2020* Strategic Alternatives – DfT IRP team in conjunction with Mott MacDonald (based on previous 2016 alternatives work by Atkins, updated in *2021* as part of IRP)	Network Rail Sequence 4.0 and 4.1 assured costs – *February – September 2021* HS2 Infrastructure: HS2 Ltd Baseline 2.0 estimates – *December 2020* Estimates for all networks assessed based on assured costs with some scope revisions reflecting work with external consultants
Price base	2019	2019
Contingency (added to base cost estimates to reflect risk/ maturity of design)	HS2 Reference Class Forecasting (44%) Conventional network infrastructure interventions and alternatives: 66%	HS2 Reference Class Forecasting (44% - 48%) - used for HS2/NPR "touchpoints" Network Rail costs: 66%
Assurance	HS2 infrastructure costs have been through HS2 Ltd, DfT and P-Rep assurance Conventional network costs carry a 'low' level of assurance	HS2 infrastructure costs have been through HS2 Ltd, DfT and P-Rep assurance Network Rail costs have been through Network Rail Assurance Boards

4.21 Operating costs have been taken from two sources:

- The Baseline Operating Cost Model (BOCM) for HS2 related operating costs.
- TfN's NPR OPEX Model for NPR related operating costs.

4.22 Both models draw upon the operating characteristics of their relevant scheme and the existing network based on knowledge of the cost of operating rail services.

Uncertainty

4.23 DfT's recently published TAG uncertainty toolkit sets out the requirement to consider uncertainty across all elements of modelling and appraisal. In particular, it highlights the challenge in forecasting future travel demand and the associated benefits and costs over a 60-year appraisal period given the inherent uncertainty in forecasting key drivers of travel demand such as economic and population growth, spatial distribution of population, as well as behavioural and technological changes.

4.24 The IRP analysis has also been developed against the backdrop of the COVID-19 pandemic and the increased uncertainty around future travel demand which that has brought. As well as incorporating post-COVID economic and population forecasts from July 2020 in the analysis, the sensitivity analysis undertaken considers the impact of a reduction in long-term rail demand due to behaviour change as a result of COVID. This leads to a 17% reduction in demand throughout the appraisal period. For the majority of scheme options, this low demand sensitivity reduces the benefit cost ratio (BCR) such that the VfM falls by one category (in both 60- and 100-year scenarios). The exceptions are for options where the core VfM assessment is already poor (VfM remains poor) and the Eastern Leg Hybrid to Sheffield option which remains low VfM.

4.25 The standard appraisal period for transport investment is 60 years. Recent changes to TAG unit A1.1 set out considerations under which a longer appraisal period may be assumed. Where an investment proposal will develop an asset with an economic lifespan of more than 60 years, it is reasonable to assess the impacts of that asset over a longer period. This is subject to consideration of the increased uncertainty around the assessment of impacts beyond the 60-year appraisal period. Analysis of the impacts of schemes beyond 60 years must include an assessment of maintenance, renewal, and operating costs as well as of the benefits.

4.26 Most of the options considered in the IRP have significant new build infrastructure designed to last longer than the standard 60-year appraisal period. For this reason, we have also assessed VfM over a 100-year appraisal period under two different demand scenarios, both the core scenario and the low demand scenario which captures the potential for long-term behavioural change from COVID-19.

Presentation of VfM categories

4.27 The lower end of the Value for Money ranges assumes lower demand brought about by behavioural change from COVID-19. The higher end of the range is underpinned by a reference demand forecast with no long-term COVID-19 behavioural change assumed, although shorter term impacts (including from near-term revisions to economic growth rates) are included. The higher VfM range for the NPR networks is also based on descoped capital cost estimates. This range is sufficiently broad to provide evidence on the relative value of each of the scheme options, while reflecting the large uncertainty inherent in the analysis.

4.28 Due to the nature of the assumptions made to develop the VfM range presented, particularly where a 100-year appraisal period is assumed, the ranges should not be directly compared to VfM assessments for other schemes assessed over a 60-year period.

4.29 The analysis described above has been used to generate adjusted Benefit Cost Ratios (BCRs) for each of the IRP options, capturing changes in transport user benefits, revenues and costs as well as the static economic impacts described above. These underpin the VfM categories and ranges assigned for each option. Given the early stage of option development, the VfM categories have informed a relative assessment of the different options rather than provide an absolute estimate of the value for money of individual schemes.

4.30 As described above, emerging analysis of the options informed by outputs from the updated models suggest that forecast benefits and revenues may be lower for all Eastern Leg options and higher for NPR options. While any updated VfM assessment is expected to fall within the ranges presented here, those ranges may narrow as further analysis is taken forward. There are also a number of factors which have yet to be incorporated in the analysis including a full assessment of wider economic impacts associated with households and firms relocating, and sensitivity testing around higher demand scenarios (where population and economic growth is higher than assumed under central assumptions). Overall, we anticipate this analysis would demonstrate conditions under which VfM of schemes would be higher.

4.31 The schemes in consideration within the IRP will be subject to separate individual business cases as they are developed further. These business cases will provide a more developed and detailed view of scheme VfM and reflect emerging evidence on the impact on long-term rail demand of the COVID-19 pandemic.

Figure 7: A summary of the analytical tools and the appraisal assumptions used to assess scheme options within the IRP

	HS2	NPR
Models	**PFM (version 9)** – model used in HS2 business case to estimate transport user benefits **WITA** (Wider Impacts in Transport Appraisal) – used to	**NoRMS version 1D** (Northern Rail Modelling System) – model used in NPR business case used to estimate transport user benefits

	estimate static wider economic impacts (agglomeration) **BOCM** (Baseline Operation Cost Model) - used to estimate operational costs	**NELUM** (Northern Economy Land Use Model) – used to estimate static wider economic impacts as per WITA **NPR OPEX Model** – used to estimate operational costs
Rail Demand Assumptions	Post-COVID demand forecasts based on July 2020 OBR forecasts. Low end of VfM assumes lower long-term demand due to behavioural change following COVID	Post-COVID demand forecasts based on July 2020 OBR forecasts. Low end of VfM assumes lower long-term demand due to behavioural change following COVID
Opening Year Assumptions	2038 for Western Leg 2040 for Eastern Leg	2040
Appraisal Period	60-year appraisal period with a 100-year appraisal period sensitivity	
Assurance	Internal assurance by DfT/IRP analysis, with external third-party check of appraisal workbook	

5 Strategic assessment of options

Summary of outputs

5.1 This section presents the results of the analysis completed for the HS2 Eastern Leg and Northern Powerhouse Rail options. Analysis is presented in multi-criteria tables to provide a holistic assessment of the impacts of each option. Also highlighted are the trade-offs between different strategic objectives which were considered when deciding on the preferred options. As set out in section 3, detailed assessment of HS2 Phase 2b Western Leg (Crewe-Manchester) options will be presented in the business case published alongside the deposit of the High Speed Rail (Crewe-Manchester) Bill and is not included here.

5.2 The analytical outputs presented here provide additional evidence to that presented in the NIC's Rail Needs Assessment which found that prioritising regional links, such as those from Birmingham to Nottingham and Manchester to Leeds, has the potential to deliver the highest benefits.

Outputs (including Value for Money)

5.3 The presentation of the multi-criteria analysis tables reflects the relative assessment made of different options rather than analysis of absolute impacts. Option assessment is shown through colour grading in the multi criteria analysis tables.

5.4 The multi-criteria analysis tables show the VfM ranges for each option. The colour grading is based on the benefit cost ratios calculated under core appraisal assumptions (60-year and 100-year appraisal periods, central demand forecast), with the highest Benefit Cost Ratio ranked highest and vice-versa.

HS2 Phase 2b Eastern Leg

Figure 8: Eastern Leg Options Multi-Criteria Analysis Table

Best ◄► Worst			Upgrades Only	Hybrid to Sheffield	Hybrid to Leeds	Hybrid via Newark	Hybrid via Erewash	Full Eastern Leg
Cost			c. £9bn	c. £13bn	c. £17bn	c. £24bn	c. £28bn	c. £35bn[a]
Value for Money (60 year appraisal)			Low-Medium	Low	Poor-Low	Poor-Low	Expected to be similar to End State Newark	Poor-Low
Value for Money (100 year appraisal)			Medium-High	Low-High	Low-Medium	Low-Medium	Expected to be similar to End State Newark	Low-Medium
Decarbonisation *(All options potentially compatible with targets and commitments)*			Higher construction carbon for new lines requiring greater modal shift/operation savings to offset.					
Mitigation of adverse local impacts			Majority of impacts can be mitigated, but greater impacts from more new line					
Delivery timescales			2027-35	2027-45	2027-45	2027-45	2027-45	2040-45
Delivery disruption to existing network			High	Medium	Medium	Medium	Medium	Low
Train service outputs		**Current**			**Minutes**			
Connectivity improvement	London-Derby	86	57	58	58	58	58	83[b]
	London-Nottingham	92	80	57	57	57	57	83[b]
Colour Coding: Within 5mins of fastest journey time - Dark Green; Within 15 mins of fastest journey time - Light Green; Within 30mins of fastest journey time – Light Orange; Outside 30mins of fastest journey time – Dark Orange	Nottingham-Birmingham	74	74	26	26	26	26	55[b]
	Nottingham-Leeds	103	103	103	103	38	68	51[b]
	London-Sheffield	118	86	87	87	87	87	87
	Sheffield-Leeds	40	40	40	27	27	23	24
	London-Leeds	133	113	113	104	97	93[c]	81
	Birmingham-Leeds	118	117	89	85	66	61[c]	49
	London-Newcastle	169	148[d]	148[d]	148[d]	140	148[d]	137
	Birmingham-Newcastle[e]	206	194	167	167	119	167	117
	York-Newcastle[e]	56	47	47	47	47	47	49
	London-York	112	98	98	98	93	98	84
Capacity - % increase in seats (to/from London network)[d]	E Mids (Derby/Nott/Toton/EMP)	<1,500[f]	c. +160%	c. +160%	c. +160%	c. +230%	c. +260%	c. +310%
	Sheffield	<750[g]	c. +120%	c. +120%	+160%	c. +160%	c. +160%	c. +120%
	Leeds	<1,250	c. +30%	c. +30%	c +140%	c. +250%	c. +200%	c. +280%

5.4 The multi criteria analysis demonstrates some of the key trade-offs which arise when considering different options for the Eastern Leg, in particular the trade-offs between affordability and achieving other key objectives including decarbonisation and improving connectivity and capacity. This is particularly evident when comparing an Upgrades-only option for the Eastern Leg to the other Hybrid options. While upgrades are relatively more affordable with lower costs also boosting the relative VfM assessment, this option scores poorly when compared to the preferred Hybrid to Sheffield option outlined in the report, on contribution to other objectives, particularly around decarbonisation and capacity and connectivity boosts.

5.5 A Hybrid Eastern Leg option such as the Newark option delivers a greater connectivity and capacity boost compared to the Hybrid to Sheffield option. The Newark and Erewash options provide shorter journey time and increased capacity

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[a] Unlike the other packages this total does not allow for full MML electrification or for investment in the ECML
[b] via change at Toton
[c] Assumes call in East Midlands
[d] 145 minutes possible non-stop
[e] Stopping patterns vary
[f] Approximately 1500 during peak-periods and 1000 during non-peak periods.
[g] Approximately 750 during peak-periods and 580 during non-peak periods.

improvements across some destinations, such as between Leeds and Birmingham compared to the Sheffield option. Hybrid Newark would see large improvements in capacity and connectivity from the West and East Midlands to Leeds, Doncaster, York, and the NE, as well as potentially Lincoln, and further improvements in London journey times from Yorkshire, the North East and Edinburgh. However, Hybrid to Sheffield is more affordable and cost effective than the Newark option and would have fewer local adverse impacts. The Hybrid to Sheffield option has been assessed as better VfM than the Hybrid to Newark option.

5.6 The Hybrid to Leeds option performs better on connectivity and capacity than the Hybrid to Sheffield option, reducing journey times from Leeds to London, Birmingham, and Sheffield, but not as far as the Newark option or full Eastern Leg. It is also more expensive and represents lower value for money than the Hybrid to Sheffield option.

5.7 The full Eastern Leg makes the strongest contribution to capacity, quadrupling capacity between London and the East Midlands and more than trebling capacity between London and Leeds. However, it performs worse against VfM and affordability criteria, compared to the Hybrid to Sheffield option which performs similarly on many metrics including delivery, transport disruption and connectivity boost.

Northern Powerhouse Rail

5.8 A multi-criteria table summarising the performance of NPR options assessed is shown in Figure 9. Affordability varies with scope of the network under each option with the preferred IRP option delivering similar journey time outputs on Manchester-Leeds and Liverpool-Manchester corridors as more costly options.

Figure 9: NPR Options Multi-Criteria Analysis Table

Best ◄——► Worst				On-network upgrades only		Hybrid Core Network		Potential Wider Network		TfN preferred	
Cost				£6bn		c.£17bn		c.£25bn		c.£46bn	
Value for Money (60 years)				Expected to be higher than the Potential Wider Network		Expected to be lower than the Potential Wider Network		Poor-Low		Poor	
Value for Money (100 years)											
Decarbonisation *(All options potentially compatible with targets and commitments)*				Higher construction carbon for new lines requiring greater modal shift/operational savings to offset							
Mitigation of adverse local impacts				Majority of impacts can be mitigated but greater impacts from more new line							
Delivery timescales				2025-35		2025-45		2025-45		2025-50	
Delivery disruption to existing network				Medium/High		Medium/High		Medium		Medium/High	
Train service outputs		Minutes	Trains/hr	Minutes	Trains / hr	Minutes	Trains / hr	Minutes	Trains / hr	Minutes	Trains / hr
Connectivity improvement, (fast and semi-fast trains only)	Liverpool – Man Airport	71	1	71	1	26	4	23	4-5	21	4
	Liverpool-Manchester Piccadilly	50	4	39	3	35	6	32	6	29	6
	Manchester – Leeds	55	5	41	6	33	8	33	8	29	10
	Man Airport – Leeds	90	2	83	2	45	8	45	8	39	8
Colour Coding Within 5mins of fastest journey time - Dark Green Within 15 mins of fastest journey time - Light Green Within 30mins of fastest journey time – Light Orange Outside 30mins of fastest journey time – Dark Orange	Manchester – Bradford	55	2	53	2	53	2	30	6	20	6-8
	Huddersfield –Bradford	37	1	37	1	37	1	12	4	37	1
	Bradford – Leeds	20	4	20	4	12	6	10	6-8	8	10
	Leeds – Liverpool	106	2	78	2	73	4	70	4	61	4
	Manchester –Sheffield	50	2	40	3	50	2-3	40	3-4	33	4[a]
	Sheffield – Hull	77	1	77	1	77	1	70	2	70	2
	Leeds –Halifax	34	4	34	4	27	4	24	4	34	4
	Leeds – Hull	57	2	57	1	57	2	50	2	48	2
	Leeds – Newcastle	81	3	76	2-4	76	3	76	3	74	4
Capacity % increase in seats	Liverpool – Manchester			38%		268%		268%		268%	
	Manchester - Leeds			92%		299%		407%		397%	

5.9 Like the options on the Eastern Leg, the NPR Upgrades Only option is more affordable and is likely to be higher VfM relative to the preferred Hybrid Core Network outlined in the report. However, the Upgrades only option scores poorly on how it delivers against other strategic objectives including decarbonisation, capacity, and connectivity in comparison. Capacity between Liverpool, Manchester and Leeds is more than doubled in the Hybrid Core option compared to Upgrades Only, with journey times slashed between Manchester Airport and other NPR destinations.

5.10 The Wider Network performs better than the preferred Hybrid Core option on capacity and connectivity boosts. However, it is more expensive and mitigating local impacts, while achievable, will be likely to require greater effort. However, it comprehensively outperforms TfN's preferred network.

5.11 TfN's preferred network provides the greatest increase in capacity and connectivity, but scores lowest on affordability and VfM. The Hybrid Core delivers similar journey times (and the same level of NPR services) in the Manchester-Liverpool and Manchester-Leeds corridors to TfN's preferred options, is likely to represent higher VfM and costs at least £18bn less than the cost of TfN's preferred option for the

[a] 2 trains per hour via Marple and 2 trains per hour via Stockport.

same corridors. For example, Manchester to Leeds is only 4 minutes faster under TfN's preferred network, with an equivalent capacity uplift compared to the Hybrid Core option. As the Core also includes some of the more costly elements of the wider network this implies that the benefit cost ratio is likely to be lower than that for the Wider network but higher than the TfN preferred options on the same corridors.